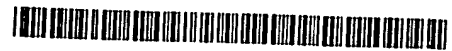


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Holmes, Mesa, AZ 85204 (US). **HUSTON, Darrin**; 37330  
- 246th Avenue S.E., Enumclaw, WA 98022 (US).

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(74) Agent: **ANDERSON, Ronald**; Law Offices of Ronald M.  
Anderson, 600 108th Avenue N.E. Suite 507, Bellevue, WA  
98004 (US).

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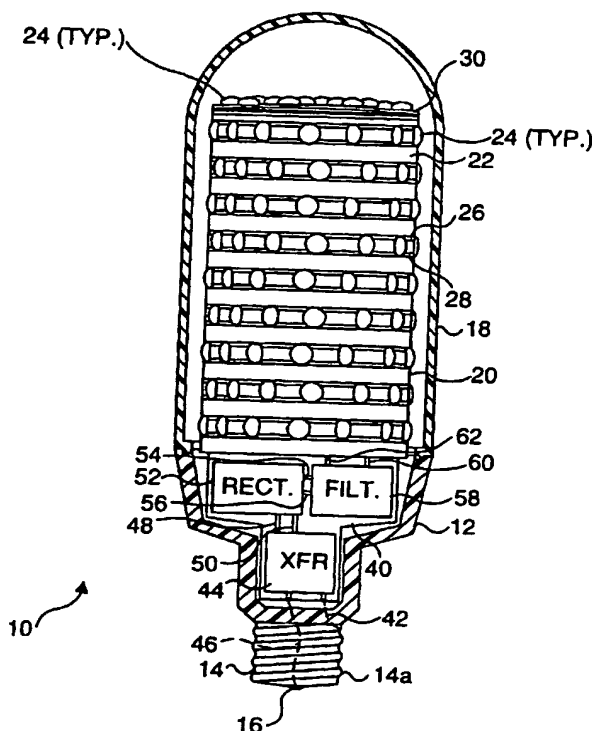
(71) Applicant: **LIGHT SCIENCES CORPORATION**  
[US/US]; 1065 12th Avenue NW, Suite E-2, Issaquah, WA  
98027 (US).

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(72) Inventors: **CHEN, James**; 2011 - 87th Place N.E., Belle-  
vue, WA 98004 (US). **WISCOMBE, Brent**; 3014 East

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ning of each regular issue of the PCT Gazette.

(54) Title: **FLEXIBLE SUBSTRATE MOUNTED SOLID-STATE LIGHT SOURCES FOR USE IN LINE CURRENT LAMP  
SOCKETS**



(57) Abstract: A lamp (10) using solid-state light emitting sources (24) is configured to be used in a conventional socket. The lamp includes a flexible substrate (22) on which are mounted a plurality of light emitting sources (24), such as light emitting diodes "LEDs" in spaced-apart array. A flexible substrate (22) configured as a generally rectangular panel formed into a cylindrical shape includes a plurality of conductive traces (26, 28) to which the LEDs are connected both mechanically and electrically. The flexible substrate (22) is then enclosed within a light transmissive translucent cover (18). The base (12) is shaped and configured to be threaded into a conventional incandescent light socket (one- or three-way) and includes a center terminal 16 through which AC line power is supplied to a power supply in the base. In a different embodiment, the light sources (24) are mounted on a flexible substrate formed as a strand or thread (68) that is wound in a helix around a cylindrical support (76).

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**FLEXIBLE SUBSTRATE MOUNTED SOLID-STATE LIGHT SOURCES  
FOR USE IN LINE CURRENT LAMP SOCKETS**

**Field of the Invention**

5 This invention generally pertains to a flexible substrate on which a plurality of light sources are mounted, and more specifically, to a plurality of solid-state light sources mounted on a flexible substrate for use in a lamp to provide room illumination.

**Background of the Invention**

10 Incandescent bulbs are one of the least efficient light sources, yet they still comprise a substantial portion of the lighting used in homes and businesses. It has long been recognized that fluorescent lighting and halogen lamps produce light much more efficiently and last substantially longer, yet even in new construction, incandescent bulbs are often used instead of the more efficient alternative types of bulbs. One of the causes delaying the general acceptance and greater use of more  
15 efficient lighting has been the initial cost of non-incandescent lighting. Although the total cost of installation and the energy required for operating non-incandescent lighting systems is substantially less than incandescent lighting, the initial cost can be significant and often discourages the installation of alternative lighting fixtures. Moreover, home and business owners are often  
20 reluctant to replace an incandescent bulb fixture with a relatively expensive fluorescent lamp and ballast assembly or other alternative lighting fixture.

Recognizing that the cost and difficulty of replacing incandescent lighting fixtures has been a significant deterrent to the acceptance of alternative lighting in new installations and the replacement of incandescent lamps with alternative  
25 lighting systems, several different compact fluorescent lamp and ballast assemblies have been developed that include a conventional incandescent lamp threaded base and which are sized to retrofit incandescent lamps in conventional incandescent lamp sockets. By using such retrofit fluorescent lamps, the need to replace the incandescent lamp with a separate ballast and other components of the  
30 type normally required for a fluorescent lamp is avoided. Although retrofit

fluorescent lamps are substantially more expensive than the incandescent bulbs they replace, the retrofit lamps have a much longer expected life and use much less electrical power to produce a light output equivalent to that of the incandescent bulb that they replace.

5           Unfortunately, many people are unwilling to pay the cost of a retrofit fluorescent lamp, even though they may recognize that these lamps will provide long-term savings. The problem appears to be that the initial cost of retrofit fluorescent lamps is too high and the non-incandescent lamps, although they may last for several thousand hours, will eventually dim and fail, requiring  
10 replacement. What is needed is a different type of alternative lamp for retrofitting incandescent lamps that can be made and marketed at a substantially lower cost than conventional retrofit fluorescent lamps, and which will provide greater efficiency and longer life.

          Light emitting diodes (LEDs) have recently been developed that produce  
15 white light at a substantially greater intensity than earlier LEDs of this type. In the prior art, U.S. Patent No. 5,463,280 (Johnson) discloses an LED retrofit lamp for use in replacing incandescent lamps employed in EXIT signs and the like. Instead of requiring up to 20 watts of a conventional incandescent light bulb used  
20 in an EXIT sign, this retrofit LED lamp produces about the same output level of light, only consumes about two watts of power, and can operate for at least 25 years. As described in this patent, a plurality of LEDs emitting red light (peak wavelength of 650-670 nm) are mounted on elongate printed circuit (PC) boards in a linear, spaced-apart array. The PC boards include conductors that electrically connect the LEDs in series. Two such PC boards are stacked back-to-back and  
25 connected to an alternating current (AC) line power source through a current limiting circuit. In one embodiment, the current limiting circuit includes a capacitor connected in series between the AC line and a rectifier. In another embodiment, a resistor is used to limit the current to a rectifier and through the series-connected LEDs. In still another embodiment, a switching power supply  
30 provides current to the LEDs. While the invention disclosed in this reference may be suitable for its disclosed intended use, it is not suitable for providing general ambient or task lighting, because the light emitted by the LEDs is red in color and is not uniformly distributed around the elongate glass tube in which the PC boards and current limiting power supply are housed. Instead, the light is concentrated at  
35 diametrically opposite sides of the back-to-back PC boards, which is acceptable in an exit sign that is only visible from opposite sides. Also, if any LED should fail in the series-connected string disclosed in this prior art patent by becoming

open-circuited, the failure will likely cause the entire string of LEDs to stop producing light. Clearly, this prior art device is not acceptable as a retrofit for incandescent bulbs used for general ambient room and task lighting. A more suitable solution is required if LED light sources are to be usable as replacements for incandescent bulbs in general ambient and task light applications.

#### Summary of the Invention

In accord with the present invention, a lamp is defined for use in a conventional line current powered incandescent lamp socket, for providing area or task lighting. The lamp includes a base that is adapted to electrically and mechanically engage a conventional lamp socket and thus, to receive an alternating current (AC) via electrical terminals disposed on the base. A power supply is electrically connected to the electrical terminals on the base and receives the AC at a line voltage. The power supply limits a voltage and a magnitude of an electrical current produced at an output of the power supply. A flexible substrate on which a plurality of electrical conductors is disposed is included within the lamp. The flexible substrate is formed to generally define a cylinder that has one end disposed adjacent to the base. The plurality of electrical conductors are electrically connected to the output of the power supply. A plurality of solid-state light sources are mounted on an outer surface of the flexible substrate in a spaced-apart array, so that light emitted by the solid-state light sources when they are electrically energized is distributed radially about an entire circumference of the lamp. Each of the solid-state light sources is electrically connected to the plurality of electrical conductors disposed on the flexible substrate, so that the light sources are energized by the electrical current from the power supply. A generally cylindrical light transmissive envelope having an end attached to the base encloses the flexible substrate and the plurality of solid-state light sources. This light transmissive envelope protects the plurality of solid-state light sources, while transmitting the light that they emit.

Preferably, the plurality of solid-state light sources comprise light emitting diodes that emit a white light, although it is also contemplated that other types of solid-state light sources can instead be used.

The plurality of conductors disposed on the flexible substrate are preferably configured to electrically couple at least a portion of the plurality of solid-state light sources in parallel. In at least one preferred form of the invention, the power supply includes a transformer, and can also include a rectifier. The power supply is preferably disposed inside the base of the lamp.

5        Either a conductive adhesive or solder can be used to mount the plurality of solid-state light sources on the flexible substrate. In one embodiment, the plurality of solid-state light sources each include at least one terminal that is coupled to at least one of the plurality of conductors on the flexible substrate by a conductive lead.

10        A cylindrical support is employed for the flexible substrate in one embodiment, and the flexible substrate comprises an elongate thread on which the plurality of solid-state light sources are mounted in a linearly spaced-apart array. The elongate thread is helically wound around an outer surface of the cylindrical support, with the plurality of solid-state light sources disposed so as to emit light radially outward relative to a central axis of the cylindrical support.

15        For use in retrofitting a conventional three-way light bulb, the base includes three electrical terminals that are adapted to electrically connect with corresponding terminals of a three-way incandescent lamp socket. The three electrical terminals of the base are connected to corresponding different input terminals of the power supply. In this embodiment, the plurality of solid-state light sources are divided into at least two portions, and the power supply responds to application of an AC line voltage to specific input terminals to selectively energize the portions of the plurality of solid-state light sources, thereby varying a light intensity produced by the lamp as a function of the input terminals of the power supply that are energized with the AC line voltage.

20        The flexible substrate, or cylindrical support, preferably also includes an outer end on which a plurality of the solid-state light sources are also mounted in a spaced-apart array.

#### 25        **Brief Description of the Drawing Figures**

      The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

30        FIGURE 1 is a cross-sectional view of a first embodiment of a lamp in accord with the present invention;

      FIGURE 2 is a flexible substrate and a plurality of solid-state light sources for use in the lamp of FIGURE 1;

35        FIGURE 3 is a cross-sectional view of a second embodiment of a lamp that includes a flexible substrate strand on which are mounted a plurality of solid-state light sources;

FIGURE 4 is a section of the flexible substrate strand that is helically coiled around a support in the embodiment of FIGURE 3;

FIGURE 5 is an elevational view showing a top portion of the support of FIGURE 4 on which the flexible substrate strand extends in a helical coil;

5      FIGURE 6 is an elevational view of a conventional table lamp for a three-way incandescent bulb that has been retrofitted with a three-way lamp configured in accord with the present invention;

FIGURE 7 is a bottom view of the three-way lamp shown in FIGURE 6;

10      FIGURE 8 is a view of the base of the three-way lamp shown in FIGURES 6 and 7, illustrating the leads connected to the terminals on the base;

FIGURE 9 is a schematic block diagram illustrating a simple power supply for the three-way lamp of FIGURE 6;

15      FIGURE 10 is an elevational view of a solid-state light array formed by wrapping a double helix of the flexible substrate strands shown in FIGURE 4 around a central cylindrical support;

FIGURE 11 is an elevational view showing a top portion of the support of FIGURE 10 on which the flexible substrate strands extend in double helical coils;

FIGURE 12 is an enlarged isometric view of a portion of a solid-state light array mounted on the flexible substrate strand shown in FIGURE 4;

20      FIGURE 13 is an isometric view of a portion of a different embodiment of a solid-state array on a flexible substrate strand; and

FIGURE 14 is an enlarged cross-sectional view of the flexible substrate strand shown in FIGURE 13.

#### Description of the Preferred Embodiments

25      FIGURES 1 and 2 show details of a first embodiment of a lamp in accord with the present invention, which is designed for use in a conventional AC light socket, for example, to replace or retrofit a conventional incandescent bulb. In terms of its external appearance, a lamp 10, which is shown in the cutaway view of FIGURE 1, may appear similar to fluorescent lamps that are designed for use in  
30      incandescent lamp sockets. However, unlike fluorescent lamps, the present invention does not use a fluorescent tube as a light source. Furthermore, it has a substantially longer expected life than such fluorescent lamps do and a much, much longer expected lifetime than a conventional incandescent lamp. It should also use substantially less power than even fluorescent lamp assemblies of  
35      equivalent light output.

Lamp 10 includes an injection molded plastic base 12 fabricated from an appropriate plastic material, with a hollow interior. Attached to the smallest

diameter portion of base 12 is a threaded metallic terminal 14, on which are formed threads 14a that are sized and configured to mate with corresponding threads provided in a conventional lamp socket. Electrically isolated from the metallic threads by an appropriate insulator (not shown in this view) is a center terminal 16, formed in the center of the end of base 12, and disposed so as to contact a corresponding terminal in a conventional incandescent lamp socket.

A translucent, but generally light transmissive cylindrical cover 18 is attached to base 12. Cover 18 is formed as a cylinder having a curved, closed end opposite the end that attaches to base 12. Cover 18 is adhesively connected to base 12 or alternatively, is threaded into base 12, or connected thereto by an appropriate plurality of fasteners (not shown). Cover 18 encloses and protects a light source array 20 that is disposed inside the cover.

Light source array 20 includes a flexible substrate 22 that is initially fabricated in the form of the rectangular panel shown in FIGURE 2, but the panel is then wrapped into a cylindrical shape, as shown in FIGURE 1. Light source array 20 includes a plurality of spaced-apart solid-state light sources 24, which preferably comprise LEDs. However, it is also contemplated that other solid-state light emitting sources can also be used in place of LEDs, such as laser diodes. Each of the light emitting sources are mounted in electrical contact with pairs of generally parallel extending (i.e., on the flat panel) conductive traces 26 and 28 that extend around the cylindrical shape when light source array 20 is formed into the cylinder for use in lamp 10. Connected to the upper edge of flexible substrate 22 is a generally circular flap 30 of the flexible substrate material. Conductive traces 26' and 28' extend in generally concentric circles on flap 30 and are connected through conductive traces 26'' and 28'' to conductive traces 26 and 28. Additional light emitting sources 24 are also connected to conductive traces 26' and 28', as shown in FIGURE 2.

Flexible substrate 22 is fabricated from an extremely flexible plastic material and is relatively thin to insure that it is sufficiently flexible to be formed into the cylindrical shape shown in FIGURE 1 and to enable flap 30 to be folded downwardly to close the end of the cylindrical shape. When energized, light emitting sources 24 produce a substantially white light in the preferred embodiment, and this light is directed radially outward from a central axis of the cylindrical shape of light source array 20, through cover 18. Because cover 18 is preferably translucent or internally frosted, the light emitted from the lamp is diffuse and does not appear to be emitted from discrete light emitting sources 24. Cover 18 is preferably made from a plastic material, but may alternatively be

made of glass that is preferably "frosted" on the interior, or another type of translucent ceramic material can also be used instead of plastic or glass.

5 An electrical current at an appropriate voltage and current level is supplied to conductive traces 26 and 28, and 26' and 28' from a power supply board 40, which is disposed within base 12. Each conductive trace 26/26' is electrically  
10 connected to a vertically extending conductive trace 32, and each conductive trace 28/28' is electrically connected to a vertically extending conductive trace 34. Vertically extending conductive traces 32 and 34 are disposed at opposite ends of flexible substrate 22, as shown in FIGURE 2. The ends of flexible substrate 22  
15 adjacent to the vertically extending conductive traces are adhesively joined together using a strip of adhesive tape or other appropriate adhesive, care being taken to prevent vertically extending conductive traces 32 and 34 from contacting each other and electrically shorting.

In the embodiment shown in FIGURE 1, power supply circuit board 40  
20 includes a transformer 44, a full-wave rectifier 52, and a filter 58. Transformer 44 is connected to threaded terminal 14 through a lead 42 that extends within the base, and to center terminal 16 through a lead 46, which also extends through the interior of base 12. The transformer receives an AC line voltage input from threaded terminal 14 and center terminal 16, producing a substantially lower  
25 output voltage that is conveyed through conductive traces 48 and 50 on power supply circuit board 40 and input to full-wave rectifier 52. The full-wave rectifier converts the lower AC voltage applied to its input to a full-wave rectified DC output that is input to filter 58 through conductive traces 54 and 56. Filter 58 smoothes the filtered DC that is input to it, producing a DC signal of the  
30 appropriate voltage, e.g., 3-5 volts, and with sufficient current to energize each of the plurality of light emitting sources 24 used within lamp 10, i.e., from about 5 ma to about 30 ma of current/lamp. Since in this embodiment, the light emitting sources are generally all connected in parallel to conductive traces 26 and 28, and 26' and 28', each of the light sources receives substantially the same voltage, and the required current will depend upon the number of LEDs used in the array.  
35 Since only a few milliamps of current at a relatively low voltage are required for each light emitting source, the total power requirement for lamp 10 is relatively low, yet it produces a light output equivalent to a substantially higher-power rated incandescent bulb. For example, it is estimated that a lamp in accord with the present invention, having 72 LEDs producing white light at an intensity approximately equal to that of a conventional 60 watt incandescent bulb, would only consume from about 8 watts to about 10 watts of power.



It should be noted that if LEDs are used for light emitting sources in lamp 10, rectifier 52 is not essential, since the LEDs themselves function as a rectifier, enabling current to flow in only one direction through the device when producing light. However, if rectifier 52 is omitted, the LEDs will only be energized during half of the power cycle, which will substantially reduce the total light output of lamp 10.

Turning now to FIGURE 3, a lamp 10' that is configured somewhat differently than lamp 10 is illustrated. Although appearing virtually identical from the outside, lamp 10' does not employ a cylindrically-shaped flexible substrate like that illustrated in FIGURES 1 and 2. In lamp 10', a flexible substrate strand 68, a portion of which is shown in FIGURE 4, is employed. Flexible substrate strand 68 comprises substantially the same type of material as flexible substrate 22, but instead of being formed as a sheet on which a plurality of the light emitting sources are disposed in spaced-apart array in two dimensions, flexible substrate strand 68 is formed in an elongate shape having a width about equal to that of each light emitting source 24, and a substantially longer length. Conductive traces 70 and 72 extend generally parallel to each other along opposite sides of the top surface of a flexible substrate 74 (in FIGURE 4) comprising flexible substrate strand 68. Light emitting sources 24 are then electrically and mechanically mounted to conductive traces 70 and 72 so that the light emitting sources are energized by an electrical current conveyed thereby. In lamp 10', a cylinder 76 fabricated of plastic, phenolic resin, or other lightweight preferably electrically insulating material provides a support for flexible substrate strand 68, which is wrapped around cylindrical support 76 in a helical spiral. As shown in FIGURE 5, cylindrical support 76 is attached to a circular disk 66 forming an end 30' for the cylindrically-shaped support, which closes one end thereof and supports the light emitting sources at that end so that the light that they produce is directed through the end of cover 18.

In lamp 10', a power supply board 40' uses different components to provide the electrical current required to energize each of light emitting sources 24 that are mounted on flexible substrate strand 68. In power supply board 40', a capacitor 80 couples the voltage supplied from center terminal 16 through lead 46, to a limiting resistor 84, which is connected to the capacitor through a conductive trace 82. Thus, capacitor 80 and resistor 84 couple and limit AC current from the AC line source that is applied to a full-wave rectifier 88, which is connected to the threaded terminal through a conductor 90. Full-wave rectifier 88 converts the AC input to it into a direct current, which is supplied

through conductive traces 70 and 72 to flexible substrate strand 68 to energize light emitting sources 24.

It is also contemplated that a lamp in accord with the present invention may be used in a conventional three-way light socket of the type in which a switch having four positions (off, low light output level, medium light output level, and full light output level) is used to selectively control the brightness of the light produced by a conventional three-way incandescent bulb. In a conventional three-way incandescent bulb, two filaments are provided and typically rated for different wattage, for example, 50 watts and 75 watts. In this example, when the switch on a conventional three-way light socket is rotated from its off position to the low light output level position, only the 50 watt filament is energized. Upon rotating the switch to the next position, the 50 watt filament is de-energized, and only the 75 watt filament is energized. Finally, when the switch is rotated to the position for full light output level, both the 50 watt and 75 watt filaments are energized. The next rotation of the switch de-energizes both filaments in the light bulb.

A lamp 96, which is constructed in accord with the present invention, can be used in a conventional three-way lamp socket in place of or as a retrofit for a conventional incandescent three-way light bulb. In FIGURE 6, lamp 96 is shown in use in a conventional three-way light fixture 100 having a lamp base 102 with a three-way light socket 104 and a four-position switch 106. AC power is supplied to three-way socket 104 through an AC line cord 108. As is true of a conventional incandescent three-way light, lamp 96 includes threaded terminal 14 with threads 14a and center terminal 16, but also includes an annular terminal 112 around center terminal 16. Center terminal 16, annular terminal 112, and threaded terminal 14 are separated electrically from each other by insulating material 110.

FIGURES 7 and 8 illustrate details of the central, annular, and threaded terminals used on lamp 96. As shown in FIGURES 8 and 9, a conductor 114 connects annular terminal 112 to a node 132 within a power supply 120, while conductor 46 connects center terminal 16 to a node 134 and a conductor 116 connects the threaded terminal or neutral of the AC line to a node 136 in the power supply, which is grounded, i.e., is connected to the neutral side of the AC line. Node 132 is connected through a resistor 128 that limits current to each of the light emitting sources within a light string 68' mounted on a flexible substrate strand 122. A resistor 130 limits the current from node 134 that is supplied to a light string 68'', which is mounted on a different flexible substrate strand (not separately shown in this Figure, but generally similar to flexible substrate

strand 122). Light strings A and B, which are identified by reference numbers 68' and 68'', respectively, generally correspond in function to the two filaments used in a conventional three-way incandescent light bulb. It should be noted that power supply 120 is substantially simpler than the power supplies previously illustrated. However, it is also contemplated that transformers, rectifiers, and filters can be used with this embodiment, or alternatively, a coupling capacitor and a rectifier can be added to the power supply shown in FIGURE 120. Further, light string A and light string B may include different numbers of light emitting sources so that a different light output is produced by each of the two light strings.

As a further alternative, a power supply can be provided that includes a triac so that a single light string can be employed instead of two light strings. The light output of the single light string can then be controlled with an electronic switch that is activated by the power provided through the annular terminal and/or center terminal, to control the voltage and/or current supplied to the light emitting sources in the single light string. These light emitting sources in the single light string will then be controlled to emit a relatively low light level in the low light position of the three-way switch, a medium light level in the next position, and the full output light level in the third position of the switch.

A light source array 20'' for use in lamp 96 is illustrated in FIGURE 10. As shown therein, flexible light strands 68' and 68'' are wrapped in a double helix around cylindrical support 76. In this Figure, only the light emitting sources on flexible substrate strand 68' are energized. To indicate their energized state, they are represented with a bolder line, indicating that they are emitting light, while the light emitting sources on flexible substrate strand 68'' (corresponding to light string B) have not yet been energized and are represented with lighter drawn lines. Light source array 20'' includes a top 30'', details of which are shown in FIGURE 11. Flexible substrate strands 68' and 68'' spiral inwardly on the top or outer surface of end 30'', and the light they produce is directed through the end of cover 18 for lamp 96 (shown in FIGURE 6) when one or both of the light strings are energized.

FIGURE 12 illustrates details of a first embodiment for producing flexible strand 68 (or 68' or 68'') in which flexible substrate 74 includes flexible conductive traces 70 and 72 extending generally parallel along the opposite edges of one surface. At spaced-apart intervals along the surface, LEDs 142 are connected to the flexible conductive traces. A terminal 146 on each LED is electrically connected to flexible conductive trace 72 using a large drop 144 of a conductive adhesive or solder. Similarly, a large drop 140 of conductive adhesive

or solder connects an opposite terminal (not shown) on LED 142 to conductive trace 70.

FIGURES 13 and 14 illustrate a flexible substrate strand 150 that includes a thread 152 formed of the flexible substrate having flexible conductive traces 156 and 158 extending along opposite edges. A plurality of LEDs or other solid-state light emitting devices are mounted on the top surface of thread 152 using an adhesive. A terminal 164 on one side of each LED or light emitting source is connected through a flywire 162. One end of the flywire is ultrasonically or thermosonically welded to the terminal and the other end of the flywire is ultrasonically or thermosonically welded at point 160 on conductive trace 156. Similarly, on the opposite side of the solid-state light emitting source, a terminal 170 is connected through a flywire 166 or other conductive metal strip to conductive trace 156. Flywire 166 is ultrasonically or thermosonically welded to terminal 170 and to point 168 on the conductive trace at each LED. Flexible substrate strand 150 is somewhat thinner in width than the embodiment shown in FIGURE 12, and is simply a further example of how the flexible substrate strands can be configured for use in the present invention. It will be understood by those of ordinary skill in the art that other embodiments of a flexible substrate strand or thread that includes conductive traces on which the light emitting sources are mounted in spaced-apart linear array can be used within the lamps in accord with the present invention. It should also be noted that other shapes and configurations of lamps that use a flexible substrate on which light emitting sources are mounted either in a two-dimensional array or in a linear array can be employed and that the base can be configured to provide an electrical connection to other types of sockets.

Although the present invention has been described in connection with the preferred forms of practicing it and modifications thereto, those of ordinary skill in the art will understand that many other modifications can be made thereto within the scope of the claims that follow. Accordingly, it is not intended that the scope of the invention in any way be limited by the above description, but instead be determined entirely by reference to the claims that follow.

The invention in which an exclusive right is claimed is defined by the following:

1. A lamp for use in a conventional line current powered incandescent lamp socket, for providing area or task lighting, comprising:

(a) a base that is adapted to electrically and mechanically engage a conventional line current powered incandescent lamp socket, to receive an alternating current (AC) via electrical terminals disposed on the base;

(b) a power supply electrically connected to the electrical terminals on the base, said power supply receiving the AC providing an output electrical current;

(c) a flexible substrate on which are disposed a plurality of electrical conductors, said flexible substrate being formed to generally define a cylindrical shape and having one end disposed adjacent to the base, said plurality of electrical conductors being electrically connected to the output of the power supply;

(d) a plurality of solid-state light sources mounted on an outer surface of the flexible substrate in a spaced-apart array that is configured so that light emitted by the plurality of solid-state light sources when they are electrically energized by the electrical current radiates outwardly about an entire circumference of the lamp, each of said plurality of solid-state light sources being electrically connected to the plurality of electrical conductors disposed on the flexible substrate, enabling the plurality of solid-state light sources to be energized by the electrical current produced by the power supply; and

(e) a generally cylindrical light transmissive envelope having an end attached to the base, said envelope enclosing the flexible substrate and the plurality of solid-state light sources, providing protection to the plurality of solid-state light sources, while transmitting the light emitted by the plurality of solid-state light sources generally radially outward from the lamp.

2. The lamp of Claim 1, wherein the plurality of solid-state light sources comprise light emitting diodes that emit a white light.

3. The lamp of Claim 1, wherein the plurality of conductors disposed on the flexible substrate are configured to electrically couple at least a portion of the plurality of solid-state light sources in parallel with each other.

4. The lamp of Claim 1, wherein the plurality of conductors disposed on the flexible substrate extend substantially parallel along a surface of the flexible substrate.
5. The lamp of Claim 1, wherein the power supply comprises a transformer.
6. The lamp of Claim 1, wherein the power supply includes a rectifier.
7. The lamp of Claim 1, wherein the plurality of solid-state light sources are mounted on the flexible substrate with one of a conductive adhesive and solder.
8. The lamp of Claim 1, wherein the plurality of solid-state light sources each include at least one terminal that is coupled to at least one of the plurality of conductors on the flexible substrate by a conductive lead.
9. The lamp of Claim 1, further comprising a cylindrical support for the flexible substrate, said flexible substrate comprising an elongate thread on which the plurality of solid-state light sources are mounted in a linearly spaced-apart array, said elongate thread being helically wound around an outer surface of the cylindrical support.
10. The lamp of Claim 1, wherein the base includes three electrical terminals that are adapted to electrically connect with corresponding terminals of a three-way incandescent lamp socket, at least two of said three electrical terminals of the base being connected to the power supply, said power supply responding to application of an AC line voltage to specific ones of the electrical terminals to provide an electrical current to energize a predetermined portion of the plurality of solid-state light sources, thereby varying a light intensity produced by the plurality of solid-state light sources as a function of the electrical terminals that are energized with the AC line voltage.
11. The lamp of Claim 1, wherein the flexible substrate includes an end portion opposite said one end attached to the base, said end portion also including a plurality of the solid-state light sources mounted thereon in a spaced-apart array.

12. The lamp of Claim 1, wherein the power supply is disposed within the base.

13. A lamp adapted to replace an incandescent lamp in a conventional line voltage alternating current (AC) lamp socket, comprising:

(a) a base having male threads and sized so that it is adapted to be threaded into a conventional line voltage AC lamp socket, said base include electrical terminals adapted to contact corresponding electrical terminals in a conventional line voltage AC lamp socket;

(b) a flexible substrate that is formed so as to generally define a cylinder and which includes a plurality of conductive traces disposed thereon;

(c) a plurality of solid-state light sources disposed on an outer surface of the flexible substrate in a spaced-apart array, each of said plurality of solid-state light sources being connected to the plurality of conductive traces, and when energized by an electrical current, each solid-state light source emitting substantially white light that is directed outwardly away from the flexible substrate and radially outwardly from the lamp;

(d) a power supply disposed in the base and electrically connected to the terminals to enable the power supply to receive input current therefrom, said power supply being connected to the conductive traces on the flexible substrate and when supplied with a line voltage AC, producing an electrical current at a voltage sufficient to energize the plurality of solid-state light sources; and

(e) a generally cylindrical-shaped light transmissive cover sized and shaped to enclose and protect the plurality of solid-state light sources mounted on the flexible circuit, the light emitted by the plurality of solid-state light sources being transmitted through the cover.

14. The lamp of Claim 13, wherein the cover is formed of one of a glass and a plastic material.

15. The lamp of Claim 13, wherein the cover diffuses the white light emitted by the plurality of solid-state light sources.

16. The lamp of Claim 13, wherein the plurality of solid-state light sources each comprise a light emitting diode.

17. The lamp of Claim 13, wherein the power supply limits at least one of the electrical current and the voltage applied to energize the plurality of solid-state light sources to magnitudes that do not damage the plurality of solid-state light sources.

18. The lamp of Claim 13, wherein the plurality of solid-state light sources are connected in parallel to the power supply via the plurality of conductive traces.

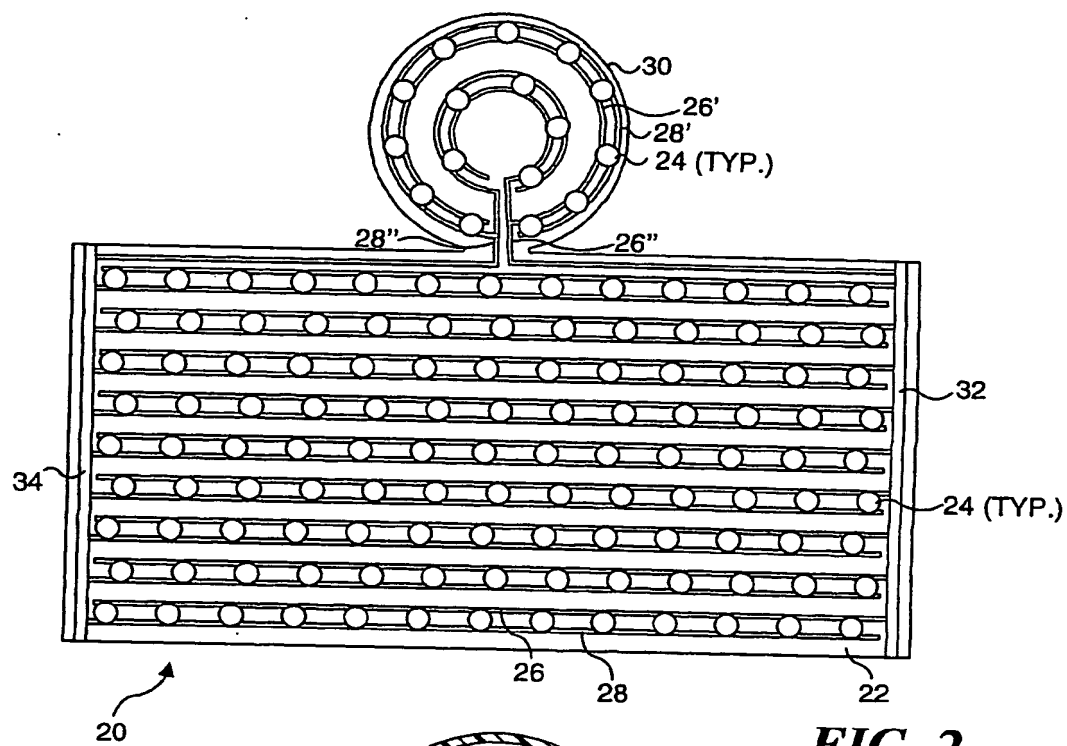
19. The lamp of Claim 13, further comprising an end section of the flexible substrate on which a portion of the plurality of solid-state light sources are mounted, said end section being disposed over and generally closing an end of the cylinder so that when this portion of the plurality of solid-state light sources is energized, light emitted thereby is directed away from the end section of the flexible substrate and out through the end of the cylinder.

20. The lamp of Claim 13, wherein the terminals include a center terminal, an annular terminal, and a threaded terminal, said center terminal and said annular terminal being adapted to electrically connect with corresponding terminals in a three-way lamp socket that includes a four-position switch, when the threaded terminal of the lamp is mated with a three-way lamp socket.

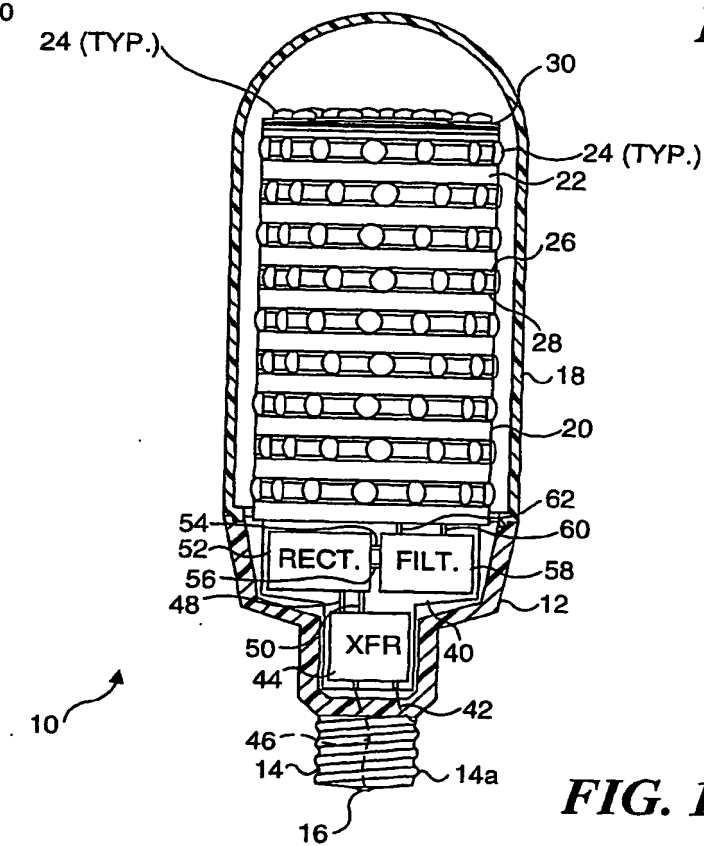
21. The lamp of Claim 20, wherein the power supply energizes a different portion of the plurality of solid-state light sources as a function of whether an AC line voltage is applied to the threaded terminal and:

- (a) the center terminal; and/or
- (b) the annular terminal.

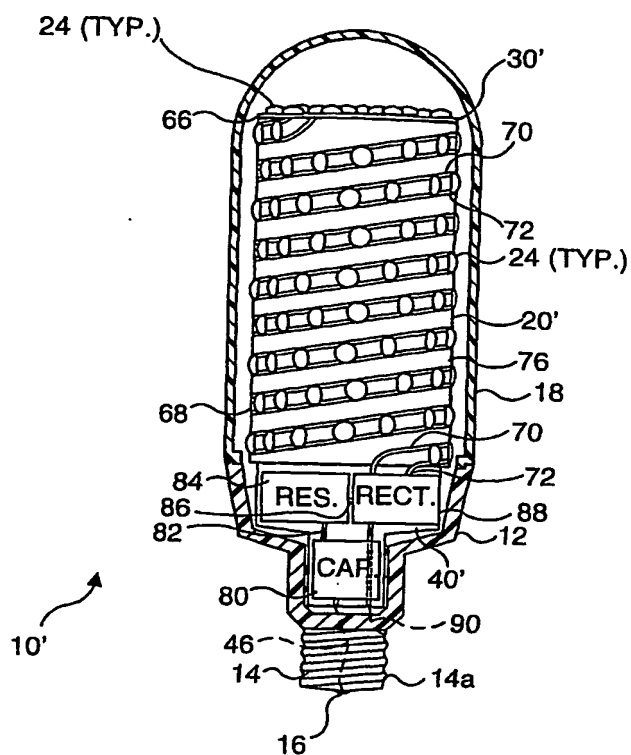
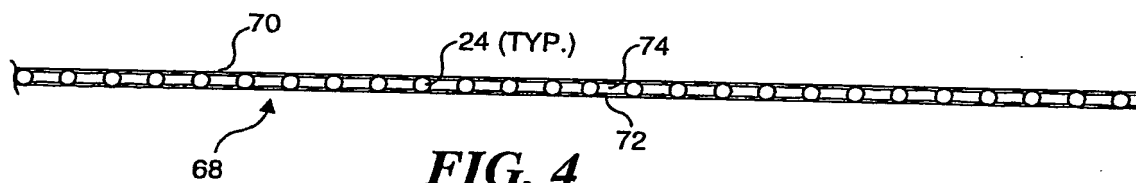
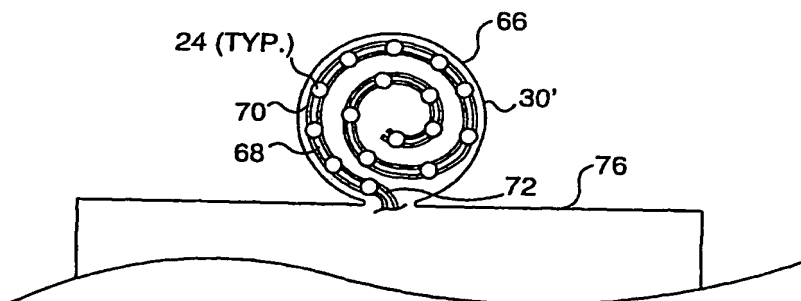


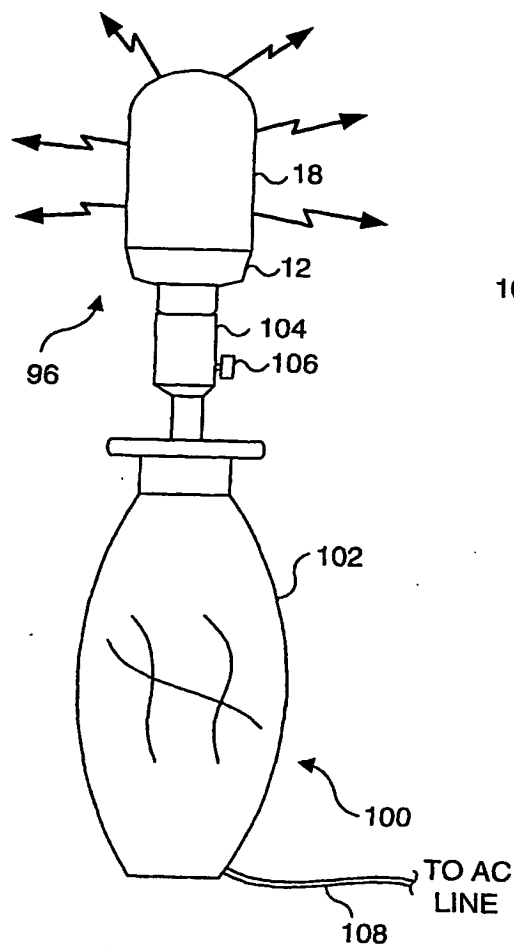


**FIG. 2**

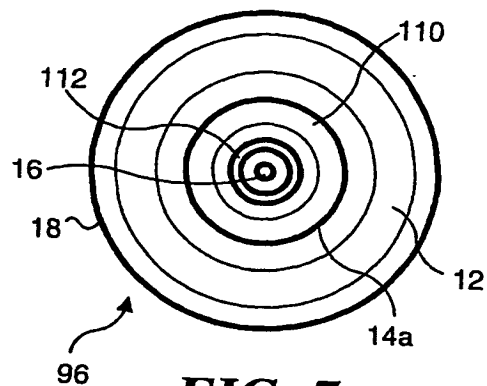


**FIG. 1**

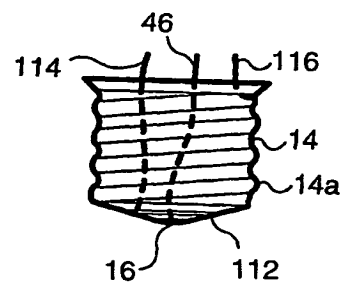
**FIG. 3****FIG. 4****FIG. 5**



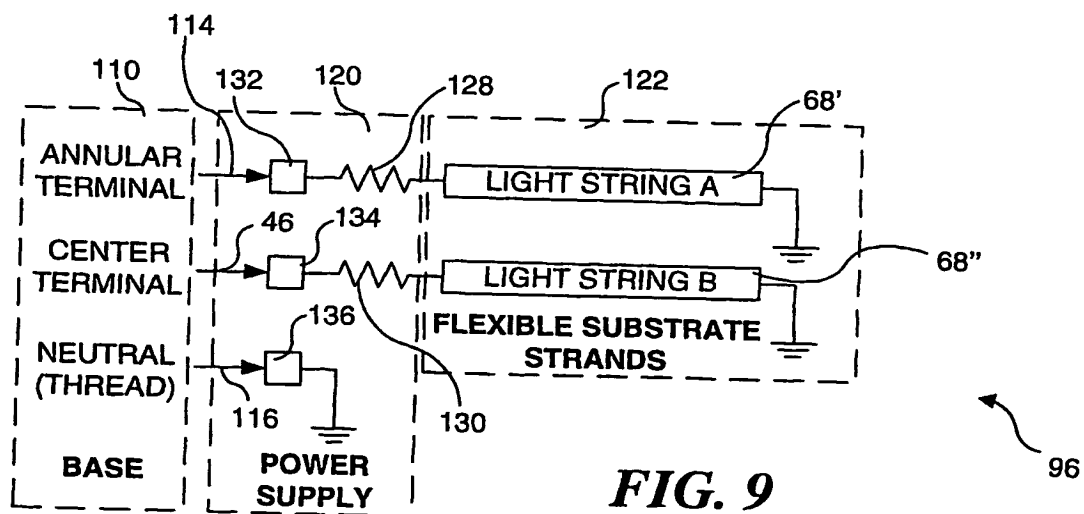
**FIG. 6**



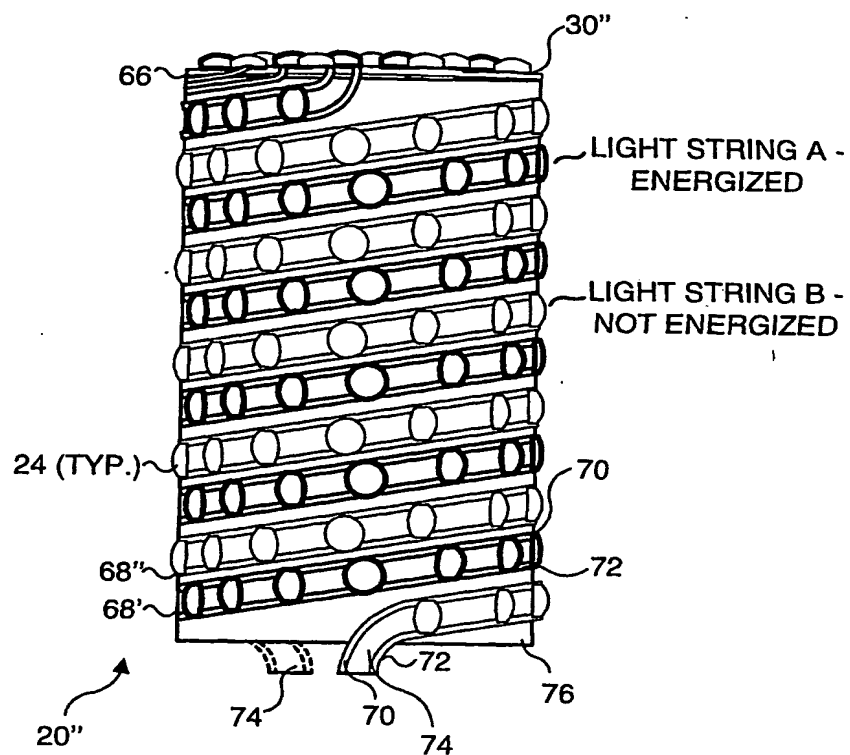
**FIG. 7**



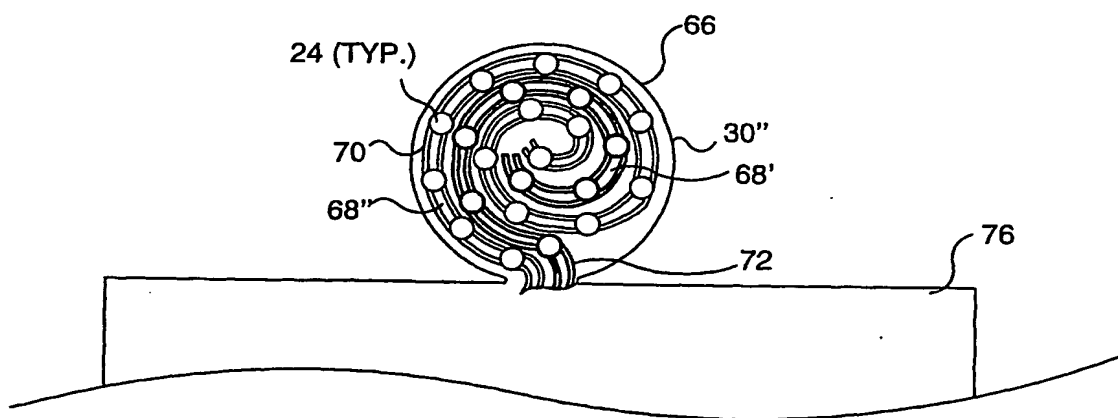
**FIG. 8**



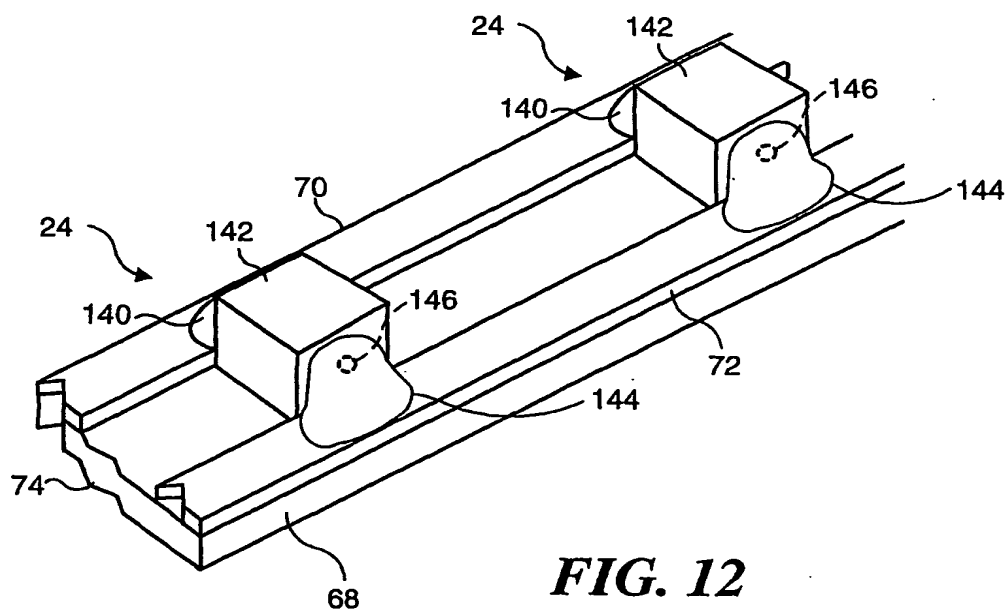
**FIG. 9**



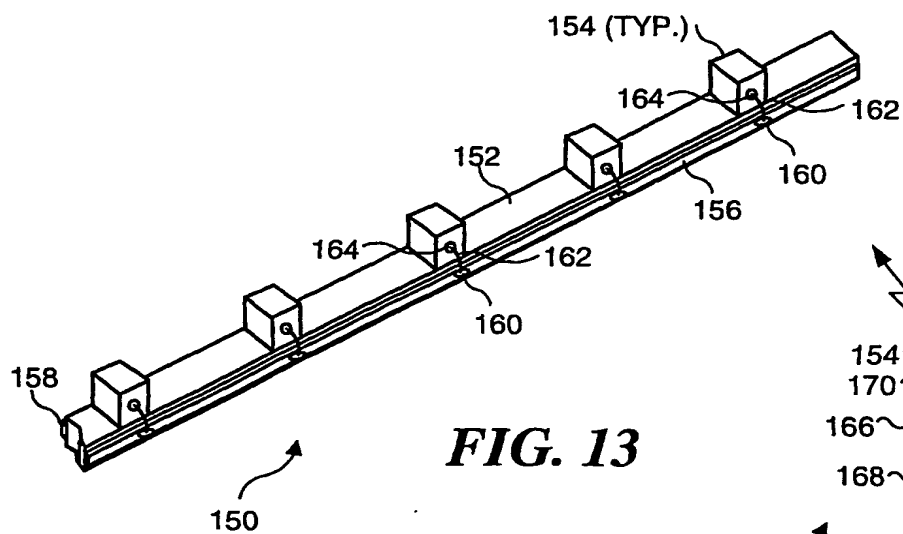
**FIG. 10**



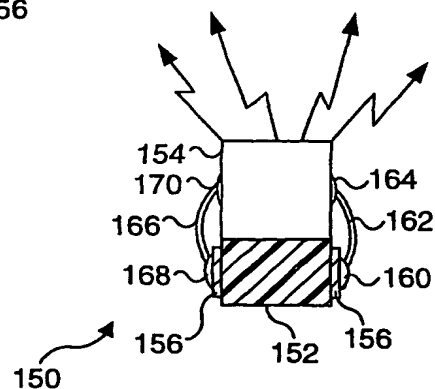
**FIG. 11**



**FIG. 12**



**FIG. 13**



**FIG. 14**

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US01/25053

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H05B 37/00

US CL :315/185 R, 192, 294; 362/800, 240

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 315/185 R, 192, 294, 250, 209 R, 185 S; 362/800, 240, 252, 227, 234, 226

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
NONEElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
NONE

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| A         | US 5,463,280 A (JOHNSON) 31 October 1995 (31.10.1995), see entire document.        | 1-21                  |
| A         | US 5,575,459 A (ANDERSON) 19 November 1996 (19.11.1996), see entire document.      | 1-21                  |
| A         | US 4,211,955 A (RAY) 08 July 1980 (08.07.1980), see entire document.               | 1-21                  |

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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|---|--|
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Date of the actual completion of the international search

24 OCTOBER 2001

Date of mailing of the international search report

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Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

HAISSA PHILOGENE

Telephone No. (703) 305-3485

*Renee Preston*